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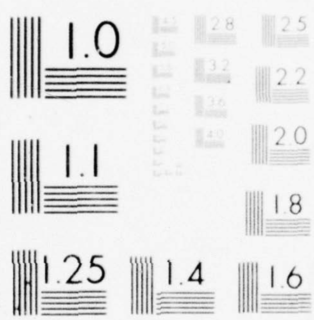

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Wright-Patterson Air Force Base, Ohio

CRITERIA FOR PREDICTING MANPOWER
REQUIRED FOR THE AFPRO CONTRACTOR
QUALITY ASSURANCE FUNCTION

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SLSR 41-76B

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a. Man-years ________ $ ________ (Contract).

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4. Often it is not possible to attach equivalent dollar values to research, although the results of the research may, in fact, be important. Whether or not you were able to establish an equivalent value for this research (3 above), what is your estimate of its significance?

a. Highly Significant   b. Significant   c. Slightly Significant   d. Of No Significance

5. Comments:

Name and Grade ________________ Position ________________

Organization ________________ Location ________________

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6 # CRITERIA FOR PREDICTING MANPOWER REQUIRED FOR THE AFPRO CONTRACTOR QUALITY ASSURANCE FUNCTION.

9 Master's thesis,

A Thesis

Presented to the Faculty of the School of Systems and Logistics

of the Air Force Institute of Technology

In Partial Fulfillment of the Requirements for the

Degree of Master of Science in Logistics Management

10

By

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has been accepted by the undersigned on behalf of the faculty of the School of Systems and Logistics in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE IN LOGISTICS MANAGEMENT

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COMMITTEE CHAIRMAN

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INTRODUCTION

According to David N. Burt, "the most important functions of purchasing are to obtain the right quality materials and service at the right time and price [1:12]." The United States Air Force (USAF) relies heavily upon its contractors for control of the quality of materials and services provided. In order to achieve its purpose, the Air Force not only specifies the level of product quality but also specifies the quality control (QC) approach which the contractor is to use. Virtually all QC operations are conducted by the manufacturer in his plant. The purchaser (USAF) attempts to avoid a duplication of QC. If contractors with effective QC programs are selected, USAF can reduce or eliminate duplication of the quality effort (1:19-22). However, neither the contractor's quality assurance (QA) organization nor that of the Air Force can function in isolation. According to AFCMDR 74-1, the contractor is responsible for performing in accordance with contract requirements while USAF QA personnel are responsible for verifying and evaluating that performance. Two principal functions are involved in satisfying the USAF responsibilities:

(1) assuring that the contractor procedures are adequate, and (2) providing a means to evaluate the contractor's effort in following his procedures. The efficient and effective integration of QA efforts of the contractor and the Air Force can help lead to purchasing the right quality materials and service at the right time and price (16:1-15).

STATEMENT OF PROBLEM

Prelude

When procurement of a new weapon system for the Air Force has been authorized, full responsibility for all actions necessary to initiate and carry out the procurement are assigned to the Air Force Systems Command (AFSC) (16:1).

The entire procurement process is accomplished as a joint effort by two distinct organizations under AFSC, the System Program Office (SPO) and the Air Force Plant Representative Office (AFPRO) (16:2). Most of the effort up to and including contract award, usually called the procurement phase, is performed by the SPO. When the contract is awarded, the AFPRO, which is located in the contractor's plant, initiates and carries out the on-site surveillance of the contractor's total production effort, culminating in acceptance of the weapon system by the AFPRO.

Thirty-five to fifty percent of the AFPRO manpower is found in the QA function (2). The prime objective of the AFPRO QA function is to insure that a contractor

operated QA program exists which meets contractual requirements. AFPRO QA personnel evaluate and verify contractor performance in achieving these contractual requirements (16). Because of the complexity of these contractual requirements, total AFPRO manpower can number several hundred for a major weapon system in a large contractor facility; for example, the AFPRO for the C-5 transport aircraft numbered approximately 250 at the height of the production program (3).

While the technical expertise required of the AFPRO QA personnel can be determined in large measure by the nature of the product involved (12:54), the specific number of QA personnel required for adequate surveillance of a major weapon system contractor is not so easily determined. Efforts by the Air Force Contract Management Division (AFCMD) to establish manning criteria for AFPRO detachment QA offices has resulted in a set of eight manpower models, one for each type of facility as determined by the product, i.e., solid rocket motors, liquid rocket motors, engines, reentry vehicles, missiles, airframe, electronics, and multiple products. These models use the number of contractor QC and inspection personnel as the only independent variable for determining the level of Air Force QA manning (5).

Problem

Currently there is no manpower model in use by AFSC for determining the optimum blend of USAF and contractor QA personnel required by each AFPRO. Since AFSC

has little direct control over the number of contractor QA personnel assigned, the problem is that of defining the significant quality variables upon which the contractor bases his QA personnel requirements. Once defined, these variables can be used to determine the optimal number of AFPRO QA personnel employed at a given contractor's plant.

BACKGROUND

Overview

The American taxpayer demands that the Department of Defense (DoD) contract wisely to obtain quality products at minimal cost (10:1). An AFPRO organization directly influences contractor performance and overall contract cost. The trade-off between product cost and QA cost is affected primarily by the level of contractor QA manning. Overall contract cost is significantly affected by the contractor's QA effectiveness and efficiency.

Need for QA Efficiency

DoD studies indicate a lack of measure as to the effectiveness of QA manpower resources (7;8;11;17). Within the context of a decreasing purchasing power of the DoD budget, proper allocation of resources becomes more than a matter of academic interest. During FY75, the DoD procurement budget was approximately 20 billion dollars. Of that amount, approximately one percent, or 200 million dollars, was spent on administering contract QA requirements (12:11). A quality cost analysis study conducted at Stanford

University under an AFSC contract questioned the system used for allocation of quality resources (6:29). The Stanford study suggested that habits develop and activities continue to be performed long after their need has ceased (6:29-30). Once a system is established, change becomes difficult.

AFCMD Policy Change

In December 1974, AFCMDR 74-1 replaced the previous AFPRO QA operational manual, AFCMDM 74-1. The new regulation advances a concept of QA which is based upon a precise definition of Government QA responsibilities accompanied by a clarification of the Government/contractor QA relationship. The approach taken by AFCMDR 74-1 is that the QA task of an AFPRO detachment can only be done effectively if applicable contract management functional interrelationships with the contractor are recognized and promoted. The theme is that QA is prevention, not correction, and that management of QA relates to the following two generalized responsibilities (16).

1. Assuring that the contractor's quality system meets the requirements of the quality provisions on contract. Normally, in order of increasing complexity, these are: (a) Standard Inspection, (b) MIL-I-45208A Inspection System, and (c) MIL-Q-9858A Quality Program (19;20).

2. Assuring that the contractor complies with all the requirements of his quality system, that defects existing in the manufactured end item are related to some inconsistency in the management system, and that required adjustments are

directed downward for correction and future prevention, rather than from the bottom up (15;16).

The instrument used for contract quality management, as introduced by AFCMDR 74-1, is the Contract Management System Evaluation Program (CMSEP) procedure (16:5). With CMSEP, the approach to contract management shifts from monitoring and inspection of material to that of evaluating the contractor's system.

Existing AFCMD Manpower Models

The research approach was to analyze the existing AFCMD QA functional manpower models and to expand upon their source, namely, the manning requirements established by the contractor. The AFCMD QA models were developed using FY73-74 data and are due to be updated during CY76 (5:1). They were developed using a linear regression technique to establish a simple relationship between AFPRO manpower requirements (dependent variable) and contractor quality personnel (independent variable). The analysis itself was performed utilizing a Management Engineering Team (MET) analysis program PACER. Examples of several models by type of product are as follows (5:3):

Airframe

Equations:	1st Shift	2nd & 3rd Shifts
	$Y = 21.75 + .05X$	$Y = 2.43 + .052X$
	$R = .944$	$R = .963$
	$SY = 6.44$	$SY = 2.13$

Missiles

Equation:

$$Y = 13.62 + .079X$$
$$R = .775$$
$$SY = 4.47$$

Engines

Equation:

$$Y = -2.45 + .081X$$
$$R = .822$$
$$SY = 3.02$$

Definitions:

Y	AFPRO QA manning
X	Contractor manning
R	Coefficient of correlation
SY	Standard error

Proposed AFCMD Manpower Models

USAF manning models, based upon contractor manning, require further clarification in that contractor manning should be based upon fundamental criteria. An attempt was made to determine the manning criteria used by the contractor and to define a model for contractor manning. This model could be used by AFCMD and future researchers as a starting point to construct AFCMD manpower models.

JUSTIFICATION

Limited Resources

The present climate within DoD in general, and the Air Force in particular, is that of limited resources (13:2-14). Significant among these resources is manpower, which equates to dollars.

Criteria used to establish and justify manpower expenditures are of more concern than ever before. Consequently, these criteria must be fully relevant. Justification of cost of any kind is assuming greater and greater importance to management and carries with it a corresponding increase in difficulty of accomplishment (18:20).

The Morgan Study

Morgan categorizes total quality costs as: (a) prevention costs, (b) approval costs, and (c) failure costs (11:33). While these titles relate to the effort of the AFPRO QA function, the preponderance, if not the total "quality" cost of the AFPRO, is manpower.

The Juran Theory

A noted author in the field of QC, Dr. J. M. Juran, proposed a theory about quality which is related to the Morgan Study. He stated:

> The basic problem of improving conformance quality may be succinctly stated; it is to prevent defects from happening. Defects that do not happen cannot become scrap losses, cause extra operations, require expensive rework, consume extensive inspection time, or result in customer complaints. In theory, defects can be successfully prevented by thorough planning for quality in such a way that all product requirements are clearly known and can be produced, and then by administering the plan so as to detect and correct deviations before they become defects [7:11-2].

Therein lies the challenge--to allocate personnel resources to QA programs in order to minimize defective items and their associated costs while maintaining an efficient QA program.

Manning Criteria

The relevance of the AFCMD QA manpower models is dependent upon whether contractor QA manning is a valid criterion. If this present manning criterion proves to be unsupportable, then other more relevant criteria are necessary. Since the current AFCMD QA models are due for updating in CY76, significant variables need to be identified so that they can be considered for the CY76 update.

CMSEP shifted the AFCMD QA approach to contract management from monitoring and inspection of material to that of evaluating the contractor's system. This approach impacts both the type and quantity of QA personnel employed by a given AFPRO. For this reason alone, a new look at AFCMD manning criteria appears justified.

SCOPE

AFCMD has responsibility for 18 contractor facilities where major weapons systems are being developed and produced. These facilities are scattered throughout the United States. The universe for this study includes all contractor plants which have a resident AFPRO.

RESEARCH OBJECTIVE

The research objective was to determine whether there exists a significant relationship between the variables associated with the defense contractors' quality

organizations and the level of manning employed by those contractors.

RESEARCH HYPOTHESIS/QUESTION

In order to accomplish the research objective, the following general research hypothesis was tested:

A relationship exists between the number of contractor QA personnel (the dependent variable) and the following independent variables:

1. Volume of contractual end items presented,
2. Corrective action hours,
3. Scrap value ($),
4. Type of product (four variables),
5. Material review actions,
6. Production personnel,
7. Total contractor personnel,
8. Total contract dollar value,
9. Number of defense contracts,
10. Number of large dollar value contracts (two variables),
11. Quality provisions (six variables).

Where a significant relationship exists between the dependent and independent variables, the research question to be answered is, "Can these significant variables be used to create an AFPRO QA manning model which is more effective and efficient than those presently used?"

Chapter 2

RESEARCH METHODOLOGY

NATURE AND SOURCES OF DATA

Data for this research effort were obtained from selected contractors now producing major weapon systems for the Air Force. The contractors selected to participate were those having contracts administered by a resident AFPRO. The AFPRO at each of the selected contractor facilities was asked to approach its respective contractor to acquire the requested data. The data elements consisted of those criteria employed by each contractor to determine the number of QA control and inspection personnel required to accomplish all necessary quality functions.

Validity of Data

Since all major weapon system contracts contain a requirement that the contractor maintain and document a quality program or inspection system which is satisfactory to the resident government Quality Assurance Representative, the assumption was made that the contractor's quality program/inspection system is in accordance with this requirement. It was also assumed that the data reported represented an accurate and valid description of the contractor's decision making process in regards to his QA manning.

Identification/Definition of Variables

The variables used in this research effort consisted of one dependent variable and 20 independent variables. The following will identify and operationally define each variable considered in the research.

Dependent Variable

Quality personnel. The total number of contractor QA, QC, and inspection personnel required to accomplish all necessary quality tasks.

Independent Variables

Volume of contractual end items presented. The average number of end items completed each quarter year by the contractor and presented for Air Force acceptance.

Corrective action hours. The average time expended each quarter year by contractor personnel in the correction of contractor generated product deficiencies. Corrective actions may be taken to correct deficiencies in product, processes, and procedures.

Scrap value ($). The average dollar value of material scrapped each quarter year as a result of handling and workmanship errors committed by contractor personnel.

Type of product. The end item on the contract categorized as rocket motors, airframe, electronics, or other. The list originally included eight separate product types but was reduced to four on the basis of the responses received.

Material review actions. The average number and types of material review actions each quarter year. Material review actions are accomplished on defective material. The four types of actions taken can be use-as-is, rework to print, repair, or scrap.

Production personnel. Defined as the total number of contractor personnel identified to production of the end items.

Total contractor personnel. The total number of contractor personnel assigned to Government contract work.

Total contract dollar value. The dollar value of all Government prime contracts and subcontracts which the contractor is currently complying with.

Number of defense contracts. The prime contracts and subcontracts which remain in the contractor's possession and require future deliveries of products to the Government.

Number of large dollar value contracts. The number of active contracts having a dollar value of ten million or more dollars presently held by the contractor. The data

are separated into production and development contracts, thus creating two variables.

Quality provisions. The level of QA effort required of the contractor by contract. The levels, in order of increasing complexity are: (a) Standard Inspection, (b) MIL-I-45208A Inspection System, and (c) MIL-Q-9858A Quality Program Requirements. Six independent variables are created by contract quality provisions. These are the number and dollar amounts of each of the three levels listed above.

GENERALIZATION

The entire set of elements, or universe, to which the efforts of this study were directed are the 18 contractors who are presently subject to AFPRO administration (5). Data collection was accomplished for 16 of the 18 contractors to whom questionnaires were submitted. Three of the contractors submitted incomplete data and were, therefore, dropped from the sample. Thus, the sample used for the study included 13 contractors. The collected data covered a period of 24 months from the fourth quarter of 1974 to the third quarter of 1976.

DESIGN OF THE QUESTIONNAIRE

The questionnaire design was a co-effort of AFCMD/QA and the researchers. A proposed questionnaire (see Appendix A), prepared by the researchers, was sent to AFCMD. AFCMD prepared the final version of the questionnaire (see Appendix B).

DATA COLLECTION PLAN

Collection of data was accomplished with the help of the 16 AFPROs mentioned above. The questionnaire from AFCMD was provided each AFPRO QA organization. As questionnaire responses were returned to AFCMD/QA (see Appendix C), they were individually assessed for information which could be construed as company confidential and such information was deleted accordingly. AFCMD summarized the releasable information by contractor in a format as illustrated in Appendix D. Contractor code numbers were assigned to the data sheets in lieu of contractor names to prevent identification of specific contractors. These codes have no significance other than providing a reference for individual questionnaires.

STATISTICAL TESTS

Selection

The research objective of this study was to determine whether contractor QA data could be related to the QA manpower resources used by that contractor. If a relationship exists, it should be possible to predict the optimum manpower requirements of an effective contractor quality organization based upon significant data parameters. The research hypothesis tests the existence of a relationship between contractor quality manning and 20 independent variables. The statistical tool selected for data analysis was multiple linear regression analysis.

Justification

Multiple regression measures the simultaneous influence of a number of independent variables upon one dependent variable--such as required manpower resources (14:611). While manning requirements may not be affected by all 20 independent variables in question, any individual or joint relationship which exists can be tested. In particular, the regression relationship is of the form

$$Y = A + B_1X_1 + B_2X_2 + \ldots + B_{19}X_{19} + B_{20}X_{20} + Z$$

where B_1, B_2, . . . , B_{20} are the "true" net regression coefficients, A is the true intercept, and $Z = Y - Yc$, the residual or stochastic error (21:266). Yc is defined as the predicted value for a given set of independent variables based upon the regression equation. The predicted parameters of the above equation become the best, linear, unbiased estimators of the true regression plane since analysis of parameter significance is based upon the least squares method (14:601). An additional advantage of multiple regression is the reduction of bias caused by the indirect effect of omitted independent variables; bias being the difference between actual and expected values and indirect effect being the effect an omitted independent variable may have (when correlated with the other independent variables) on the dependent variable (21:306).

Basic Assumptions

The use of multiple regression formulas in assessing the significance of parameters implies the assumptions that the residual errors, Z, are:

1. Clustered around a rectilinear plane,
2. Independent of each other,
3. Uniform in their scatter, and
4. For small samples, normally distributed (14:608-09).

Since each observation (the data items for one Y and the corresponding set of independent variables) was collected from a different contractor, the second assumption of independence is considered valid. The fourth assumption is considered valid in that, given a sufficiently large sample (ten or more), the distribution becomes normal (21:125). The first and third assumptions were tested during execution of the regression analysis. The computer program described below provided, as an optional feature, a plot of the residual terms against each independent variable. The plot was a useful check on the assumptions of linearity and uniformity (homoscedasticity) (14:605-09).

Computer Program

Actual analysis of data to determine both the linear regression model and to test the significance of each independent variable coefficient was accomplished using a

computer program, BMD02R, described in the Spurr and Bonini text (14:604-10). The program performs a stepwise regression which enters into the model each independent variable in order of importance, so that insigificant variables can be discarded. In the stepwise procedure, the program first calculates the simple linear regression between manning and the independent variable which explains the greatest part of the variation in manning (the dependent variable). In the next step, a second independent variable is included in the regression. The variable chosen is the one which makes the greatest additional contribution to explained variance. At each step, "a partial correlation coefficient" is printed giving the relative importance of those variables not yet in the regression equation (14:607). A number of statistical values related to inference are provided by the program. The focus of the data analysis effort was directed on the following values: (a) the regression coefficients (B_i), (b) the coefficients of simple correlation (r) between each independent variable and the dependent variable, and (c) the multiple correlation coefficient (R), which includes all coefficients of simple correlation. As previously described (Page 17), a plot of residuals versus the independent variables was analyzed to test the validity of the linearity and homoscedasticity assumptions. The choice of R, r, and B_i as the variables of interest was based upon their significance in describing the existing relationship between the dependent and independent variables. The coefficients of

simple correlation (r) describe the extent to which each independent variable influences the value of the dependent variable, or the relative explained variance of that variable. The multiple correlation coefficient (R) was used to describe the total explained variance of the regression equation, or the goodness of fit of the data. An important aspect of the value of each individual regression coefficient is that each B_i measures the change in the dependent variable (Y) per unit change in the independent variable (X_i), holding the other independent variables constant (14:551-612).

Analysis

The coefficient of multiple regression (R) was analyzed to determine the amount of variation which is explained by the regression model

$$\left(R^2 = \frac{\text{Explained Variation of Y}}{\text{Total Variation of Y}}\right) \qquad (21:341).$$

Each individual coefficient of simple correlation (r) was analyzed to determine its contribution to the total explained variation of manpower at a contractor's plant. An r value, other than zero, would indicate a degree of contribution, although it might not be significant (9:116). Analysis of the regression coefficient was used to test the degree to which each independent variable affects the dependent variable while holding all other independent variables constant.

CRITERIA TEST/DECISION RULE

The usefulness of the regression line or plane, for purposes of prediction and control, depends upon the extent of the scatter of the observations about it. If the observed values of the dependent variable vary widely about the line, estimates of the variable based upon this line will not be very accurate. The measure of the scatter of the actual observations about the regression line is called the standard error of the estimate ($Sy \cdot x$) (14:561). Given $Sy \cdot x$, inferences can be made through the use of either a test of significance or a confidence interval. Where a relationship exists between any given independent variable and quality manning (as shown by $r \neq o$), the significance of that relationship can be tested after deriving the standard error of the regression coefficient

$$S_{B_i} = \frac{Sy \cdot x}{(\Sigma x^2)^{1/2}}$$

where Σx^2 describes the dispersion of x values around their mean (14:566). Once derived, S_B can be used to determine the t statistic, $t = \frac{B_i}{S_{B_i}}$, which in turn is used to accept/reject the null hypothesis that relationship exists between X_i and Y. The BMDO2R Program computes individual F test statistics for each independent variable

coefficient relative to the significance of its contribution to the overall equation. Individual t_s statistics are directly derived from this data by the relationship

$$t_s = (F_s)^{1/2}$$

The level of significance for defining the critical value for the t statistic, t_c was set at $\alpha = .10$. The justification for this significance level was based upon the results of the computer analysis described in Chapter 3.

SUMMARY OF ASSUMPTIONS

1. The questionnaire data collected from the 16 AFPROs represent a valid sample of the variables which determine a contractor's QA manning decisions.

2. The accumulated data meet the assumptions necessary for using the stepwise multiple regression technique.

3. A statistical significance test can be designed to define the accept/reject criteria for the research hypothesis.

DEFENSE CONTRACT ADMINISTRATION SERVICES PILOT STUDY

A pilot study employing the BMDO2R Computer Program was completed using QA data obtained from the Dayton Defense Contract Administration Services (DCAS) District monthly QA report for December 1975. The objectives of the study were to:

1. Gain additional insight into the use of BMD02R stepwise multiple regression procedure.

2. Apply the BMD02R program to QA data.

3. Gain experience in the use of the BMD02R Computer Program.

Based upon the results of the pilot study, the use of the BMD02R Program appears adequate to support this research effort. As determined by the results, the assumptions of linearity, independence uniform scatter, and normal distribution also appear justified for the data used in the study.

Chapter 3

RESULTS AND ANALYSIS

Introduction

In order to keep the results and data analysis, which will be discussed, in the proper perspective, it must be emphasized that the results of any analysis are only as valid as the data used. There was no direct contact between the various AFPROs and the researchers during the data gathering phase. This was intended in order to protect the confidentiality of individual data sources. As completed questionnaires were returned to AFCMD it became apparent, through discussions with AFCMD personnel, that differences existed amongst AFPROs as to their interpretation of the information requested. As a consequence, this resulted in a number of inconsistencies and deletions in data which required the researchers to omit three contractors from their sample. This could, perhaps, have been avoided if time and direct communication had permitted the researchers to offer timely clarification. Thus, the sample size used in the final analysis included a total of 13 contractors.

Further refinement of the data was necessary to reduce the number of independent variables to less than

the number of samples. This is required by the use of the F statistic:

$$F = \frac{\frac{R^2}{P-1}}{\frac{1-R^2}{N-P}} \qquad (21:340)$$

where P is the number of parameters (total variables), N is the sample size (13), and R is the coefficient of multiple regression:

$$R^2 = \frac{\text{Explained Variation of the Dependent Variable}}{\text{Total Variation of the Dependent Variable}}$$

(21:341).

Selection of variables to be included in the analysis was based upon the availability of data for each variable as submitted by the AFPROs. In addition, the researchers conducted a number of BMDO2R computer runs to determine the sensitivity of each variable in reference to its contribution to the total regression equation. Consequently, corrective action hours was deleted because of missing data for three contractors; type of product, which included four variables, was deleted both because of its lack of significant contribution to the model and because of the small number of contractors in some product categories; and the six variables which relate to number of contracts and contract dollar amounts for the three contractual quality provisions were combined into two variables, total number of defense contracts and total dollar value of defense contracts.

The remaining ten variables, which were the basis of the analysis, described below are listed in Table 1. For each of these ten variables sufficient data existed for analysis.

Analysis of Results

As previously discussed, analysis of data to determine both the linear regression model and to test the significance of the independent variable coefficients, was accomplished using the BMD02R Computer Program. The program performed a stepwise regression for each independent variable in turn and in order of its relative contribution to the explained variation of the regression model. Where a relationship is shown to exist between an independent variable and quality manning (as shown by the stepwise partial correlation coefficient, r, being different from zero) the significance of that relationship was tested using the t statistic, t_c. The level of significance for defining the critical value of t_c was set at $\alpha = 0.10$ with three degrees of freedom ($n - P = 13 - 10$). The probability of rejecting the hypothesis that a relationship exists between the regression equation and the level of QA manning at a given contractor's plant (when such a relationship exists), therefore, is one in ten. The same criterion was used for assessing the significance of the contribution made by each variable coefficient used in the regression equation. With the significance level set at one in ten ($\alpha = 0.1$) the researchers are 90 percent

Table 1

Variables Used In First Regression

Variable Number	Variable Description
1	Total Defense Contracts
2	Total Contract Dollar Amount
3	Number of Research/Development Contracts
4	Number of Production/Spares Contracts
5	Number of Production Personnel
6*	Number of Quality Assurance Personnel
7	Average End Items Accepted, Quarterly
8	Average Material Review Actions, Quarterly
9	Average Dollar Value of Scrap, Quarterly
10	Total Contractor Personnel

*Dependent Variable

confident that the coefficients, which meet the test, actually contribute to the accuracy of the regression equation.

A summary of the multiple regression results, with the partial correlation of each independent variable, is given in Table 2. From these results the test statistic for overall significance (using 13 contractors and 10 variables) is computed as follows:

$$F_s = \frac{\dfrac{R^2}{\text{No. Parameters} - 1}}{\dfrac{1 - R^2}{\text{Sample Population} - \text{No. Parameters}}}$$

$$F_s = \frac{\dfrac{.9936}{10 - 1}}{\dfrac{1 - .9936}{13 - 10}} = 51.75$$

$$F^9_{c_3} = 5.24 \qquad \alpha = 0.10$$

Since $F_s > F_c$ and the significance of the overall regression model is established at the 90 percent confidence level, the hypothesis of no relationship is rejected. The 90 percent confidence level was deemed sufficient to establish a correlation based upon the data which were provided. The large value of the test statistic would, however, allow the same decision to be made at a confidence level of 99.5 percent as shown by:

$$F^9_{c_3} = 43.88 \qquad \alpha = .005$$

Table 2

Summary of First Regression Results

Step Number	Variable Entered	Multiple R	R^2	Increase In R^2	F Value To Enter
1	2	0.9656	0.9324	0.9324	151.6888
2	4	0.9795	0.9595	0.0271	6.6768
3	8	0.9900	0.9802	0.0207	9.4127
4	9	0.9916	0.9832	0.0031	1.4627
5	3	0.9925	0.9851	0.0019	0.8840
6	7	0.9937	0.9875	0.0023	1.1171
7	5	0.9938	0.9877	0.0003	0.1035
8	10	0.9965	0.9930	0.0053	3.0295
9	1	0.9968	0.9936	0.0006	0.2877

Significance of Individual Parameters

Based upon a 90 percent confidence interval ($\alpha/2$ = .05) for locating the true net contribution to the regression equation for each independent variable coefficient and being limited to three degrees of freedom,

$$t_c = 2.353.$$

Based upon this statistic and the relationship

$$t_s = (F_s)^{1/2} = b_i/S_{b_i}$$

the parameters listed in Table 3 make contributions significantly different from zero to the overall explained variation and include the total dollar value of defense contracts, X_2, the number of production and spares contracts, X_4, and the quarterly average number of material review actions, X_8. Of these variables, the dollar value of contracts makes by far the greatest contribution:

$$t_{X_2} = (151.6888)^{1/2} = 12.32$$

This compares to $t_{X_4} = 2.58$ and $t_{X_8} = 3.07$. For purposes of this study, the results of the analysis of the statistical significance of the nine independent variables indicate that three of the nine variables, as listed in Table 3, influence contractors in their assignment of QA personnel. The confidence level for determining significance is 95 percent.

Table 3

Significant Independent Variables--Based Upon First Regression

Variable Number	Variable Description	Coefficient	Std. Error	F To Remove
Constant		71.808		
2	Total Contract Dollar Amount	0.178	0.013	183.465
4	Number of Production/ Spares Contracts	25.023	6.182	16.382
8	Average Material Review Actions	0.011	0.004	9.4127

Comparison of Existing Vs. Predicted Contractor Manning

To complete the analysis of the data, an additional BMDO2R computer analysis was made using only the three significant independent variables described above. The results of this analysis are listed in Table 4. The new critical test statistic, F_c, is changed to:

$$F^{3}_{c_9} = 2.81 \qquad \alpha = 0.1$$

or

$$F^{3}_{c_9} = 8.72 \qquad \alpha = 0.005$$

The sample statistic, F_s, becomes:

$$F_s = \frac{\dfrac{.9802}{4 - 1}}{\dfrac{1 - .9802}{13 - 4}} = 148.52$$

Since $F_s > F_c$, the significance of the model is established. The revised test statistic for individual independent variables becomes (degrees of freedom = 13 - 4):

$$t_c = 1.833 \qquad \alpha/2 = .05$$

As part of its data analysis procedure, the BMDO2R Program computes the intercept constant and the coefficients for each independent variable used in the regression equation. Using these values the regression equation is as follows:

$$Y = 71.808 + 0.178\ X_2 + 25.023\ X_4 + 0.011\ X_8$$

Table 5 presents a comparison of the present contractor quality manning status (as recorded on the questionnaire)

Table 4

Summary of Second Regression Results

Step Number	Variable Entered	Multiple R	Multiple R^2	Increase in R^2	F Value To Enter or Remove
1	2	.9656	.9324	.9324	151.6888
2	4	.9795	.9595	.0271	6.6768
3	8	.9900	.9802	.0207	9.4127

Table 5

Quality Manning

Contractor Number	No. of QA Personnel: Actual Value	Computed Value	Residual (Difference)	Percent Difference (Residual/Actual)
173	948	935	13	0.013
214	941	990	-49	0.052
289	281	287	-6	0.021
350	379	452	-73	0.193
776	136	282	-146	0.335
867	282	285	-3	0.011
512	2568	2550	18	0.007
427	599	455	144	0.241
392	439	441	-2	0.005
746	407	362	45	0.109
383	389	196	193	0.497
133	71	127	-56	0.785
944	474	552	-78	0.164

versus the number predicted by the final regression model. The coefficient of multiple determination (R^2) for the refined model is as follows:

$$R^2 = \frac{\text{Explained Variation}}{\text{Total Variation}} = .9802$$

This relationship would indicate that the model is highly predictive of the number of a given contractor's QA personnel. Where large deviations occur, as is the case with contractors 776, 383, and 133, a number of possible causes exist. These causes could stem from one or a combination of the following conditions:

1. The contractor was significantly different than other contractors of his type and this difference, as it relates to quality manning, failed to be detected by the questionnaire.

2. All significant independent variables relating to QA manning practices were not included in the questionnaire, e.g., the age and experience of the work force, the ratio of supervisory to line personnel, number of subcontracted components to the end item, and productivity indexes. One of the major problems of a study of this type is that of identifying the most significant data parameters for testing.

3. The data reported are inaccurate. This is highly likely if the questionnaire was misinterpreted by a given AFPRO and/or if the response to the questionnaire was not based upon thorough research. In this respect, the amount and quality of data reported by various AFPROs,

as reflected by the questionnaire responses received, were not consistent. Three questionnaires had to be omitted from the study due to incomplete responses and two of the 18 AFPROs receiving questionnaires failed to respond. There is the additional possibility that some AFPROs or contractors bounded their responses to questions by restraints related to company policy and similar contingencies related to a lack of trust or interest in the questionnaire's purpose. Problems of communication and time constraints were very real contributors to possible data inaccuracies. The questionnaire responses were not available to the researchers until the week ending 17 July 1976. The questionnaires were submitted to the AFPROs on 6 May 1976.

Chapter 4

CONCLUSIONS AND RECOMMENDATIONS

Introduction

Based upon the researchers' experience in the QA field, a rule of thumb exists in industry regarding the number of QA people a contractor should have. Of course, the rule is only for approximation purposes. It simply states that the number of QA people required should roughly be ten percent of the contractor's total work force. A look at the sixteen contractors originally considered in this study shows that the number of QA people, as a percentage of total work force for each contractor, ranges from three percent to 19 percent with an average of 7.75 percent. On the surface this average is not greatly different from the ten percent rule of thumb.

The data furnished by the AFPROs regarding the contractors' methods for determining QA manning was very sketchy and included no numerical information in the way of mathematical models. However, some of the replies did contain verbal references to a number of factors which influenced quality manning decisions, e.g., a percent of production people or of total people, type of contract, peculiar quality requirements, the statement of work, overall complexity of build and test efforts, and dollar

risk in relation to mission failure. Consequently, the researchers expected that at least one of these factors would prove to be significant in the development of a QA manning model. The researchers also expected that some of the other variables represented in the data furnished by AFCMD would be significant. The number of material review actions and end items were logically the strongest candidates since these relate directly to the workload of QA people. As it turned out there were three variables which proved to be statistically significant. They were the total contract dollar value, the number of production and spares contracts, and the number of material review actions accomplished. While the number of contractor personnel ranked eighth in contribution, it was the only one of the six other variables which came close to meeting the test for significance at the 95 percent confidence level.

Table 5 contains the actual and computed values for the number of QA personnel for each of 13 contractors. Assuming that an estimated number of QA personnel is reasonable if it falls within 25 percent of the actual number of QA personnel, the table reveals that contractors No. 133, 383, and 776 do not fall within this limit. The percentage differences from their actual values are 78, 50, and 34, respectively. Each of these contractors produce rocket motors. For the fourth rocket motor contractor used in the sample (No. 746) manning was predicted within 11 percent of the actual level. Of these four contractors,

two were underpredicted (No. 407 and 383) and two were overpredicted (No. 776 and 133) by the program. Thus, the fact that each exception was a rocket motor contractor may have significance. However, being a rocket motor contractor is not sufficient by itself to create a significant variable. For the remaining four contractors, QA manning was predicted within five percent of the actual current level and the other two within 19 percent and 24 percent, respectively.

The availability of data for use in the model could be somewhat of a problem. While the total contract dollar value and the number of production contracts are easily obtained, the number of material review actions is never really known until after the fact, that is, until they have already taken place. In addition, there is a lack of consistency among contractors in their practice of recording material review actions. For example, standard repair procedures, which preclude formal Material Review Board (MRB) actions, might be used by one contractor where another contractor would record a similar type deficiency as an MRB action. Nevertheless, contractor manning is predictable based upon the data supplied by this study. Furthermore, since the AFCMD models for AFPRO quality manning are based upon contractor QA manning, the data apply to AFPRO QA manpower predictions as well. The type of data which has proven significant is readily available to all AFPROs and thus to AFCMD.

In comparing the significant variables for the AFPRO study with those used in the DCAS contractor pilot study, it was evident that the number of contracts proved to be a significant independent variable in both models. The volume of end items was significant for the DCAS contractor model but not for the AFPRO model. It appears possible that the fact that the volume of end items handled in the DCAS plants was considerably greater in nearly every case than the numbers handled by the AFPRO facilities could be the difference in whether volume of end items (variable #7) was significant. If all data requested had been available from all 18 AFPRO facilities, there may have been more similarity between the two models.

One striking result of the study is the fact that not all of the factors which the contractors stated they used to determine QA manning proved to be significant in the model. Several contractor quality managers were personally interviewed by the researchers in an attempt to determine the method used to establish QA manpower levels. None of these contractors relied upon statistical models for predictive purposes. The most common response was that of basing manning on "workload" and/or a percentage of production personnel. In some cases the actual method used was considered company confidential by the manager and was, therefore, not made available. The written responses to the questionnaires relating to the method used

were similar to the verbal responses and were in most cases deleted from the data format provided by AFCMD/QA to the researchers. To the extent that "workload" equates to contract dollar value or number of production/spares contracts, the contractor response was consistent with the study results. On the other hand, the number of production personnel did not prove to be a significant variable within the bounds of this study. Material review activity is also related to contractor workload. If the contractor QA organization is performing its function according to MIL-Q-9858A, the amount of scrap and defective material should be reduced. Therefore, MRB activity should be reduced as QA effectiveness increases.

The variables which failed to meet the test for significance are included in Table 6. A brief analysis of these variables follows:

1. The Total Number of Defense Contracts: In the sensitivity analysis referred to above (Page 24), it was determined that dollar value and number of contracts are not independent of each other. If dollar value of contracts was removed from the list of variables, the total number of contracts became significant. This was anticipated. But both dollar value and number of contracts was included in the model to cover the possibility of a large number of smaller contracts existing versus a few high dollar value contracts. The study indicates that most AFPRO contractors work with high dollar value contracts and that the total

Table 6

Non-Significant Variables

Variable Number	Variable Name	Partial Correlation	F To Enter
1	Number of Defense Contracts	0.063	0.0323
3	Number of Development Contracts	-0.013	0.0013
5	Number of Production Personnel	0.148	0.1797
7	Number of End Items--Quarterly Average	0.196	0.3180
9	Dollar Value of Scrap--Quarterly Average	0.393	1.4627
10	Total Contractor Personnel	-0.003	0.0001

dollar value is not independent of the total number of contracts.

2. The Number of Development Contracts: The partial correlation of this variable with contractor QA manning is a negative value. This follows in that the QA involvement on development contracts is usually limited in comparison to production and spares contracts. Development contracts do, however, make a significant contribution to total dollar value. Apparently, within the limited data in this study, the contribution of development contracts to the regression did not prove significant in predicting quality manning.

3. The Number of Production Personnel: Five of the 16 contractors that responded to the questionnaire used the number of production personnel in justifying their quality manning levels. The lack of significance of this variable, based upon the computer analysis, can be attributed to different standards being applied by different contractors and/or the fact that the majority of the contractors do not use this variable in their method or model for QA manning.

4. The Number of End Items: Contractors having AFPROs differ from those administered by DCAS in that AFPROs normally administer major systems acquisitions. The number of contractual end items, therefore, would tend to be less at an AFPRO contractor's plant. The smaller number of end items at AFPROs, in comparison to the dollar value and workload involved, would explain the lack of

significance of this variable.

5. The Dollar Value of Scrap: This variable relates to the effectiveness of a given contractor's QA and production departments in that scrap equates directly with improper control. The lack of significance of scrap in predicting QA manning can be attributed to the relative importance of quality versus production organizations in causing and detecting scrap. Apparently production organizations are the more important contributors.

6. Total Contractor Personnel: This variable was included based upon the rule of thumb previously mentioned (Page 36). The variable failed to justify the ten percent criterion. The probable reason for lack of significance was the variation in quality workload based upon the several types of AFPRO administered contractors.

Conclusions

The degree of confidence based upon the results of this study have to be tempered by the lack of data and the limited number of AFPROs that adequately responded to the questionnaire. Nevertheless, the high degree of correlation between predicted and actual values for contractor manning which result, when the study model is applied, indicate that the results are valid. Therefore, it can be concluded that contractors which are administered by AFPROs base their quality assurance manning on the total dollar amount of contracts, the number of production and spares contracts, and the average MRB workload.

The AFPRO QA manning models used by AFCMD to predict and justify the number of QA personnel at the various AFPROs are strictly based upon contractor QA manning. These models can be modified to include the same variables which proved significant in this study by simply substituting the study model for contractor QA manning in the AFCMD model. For example, the equation used by AFCMD/QA for engine contractor AFPROs is

$$Y = -2.45 + .081X$$

where X is contractor QA manning. Substituting

$$X = 71.808 + .178X_D + 25.023X_{PC} + 0.011X_{MRB}$$

where X_D is total contract dollar amount, X_{PC} is the number of production and spares contracts, and X_{MRB} is the average MRB workload; then

$$Y = 3.366 + .014X_D + 2.027X_{PC} + .001X_{MRB}.$$

Using this model the AFPRO at the engine contractor identified as number 173 would be justified in having 76 people. The AFCMD model would justify 74 people for the same AFPRO.

The usefulness of the manning model generated by this study is based upon the significant independent variables being better criteria for justifying AFPRO QA manning than is contractor QA manning. To the extent that the results of the study are valid, it would appear that total contract dollars, the number of production and spares contracts, and the average MRB workload of a contractor are more fundamental as a basis for manning requirements of AFPROs than is contractor manning alone. A contractor

might well be under or over manned in terms of his effectiveness or his workload and the AFPRO would at present be justified in matching that condition. By using the model with the variables generated by this study, such a condition would be avoided.

Since contractors are working on contracts in all stages of the acquisition cycle from research to full scale production, any manning model would need to consider the variables in each stage. The QA function becomes more prevalent during the production stage of the acquisition cycle. This is consistent with the study model including number of production and spares contracts as a significant variable.

A side benefit of the study model is that of predicting the contractor QA manning requirements for new contracts. The model relates manning directly to dollar value and contract numbers. As these variables increase or decrease, the contractors' manning requirements should change proportionately. Thus, the Air Force contract administration function could more effectively control the QA costs of Government contracts by using the study model as a basis for manning evaluation. The benefit of manning predictability obviously applies to the AFPRO/QA function as well as to that of the contractor.

As with any model for predicting or justifying a cost of production, gaming becomes a possibility. Since the total dollar value applies to "current" contracts, it

becomes incumbent on the contract administration function to assure that contracts are closed-out when all requirements are completed. Contracts which remain open, for reasons other than delivery of end items, should not be used to justify manning. It is assumed that the majority of the AFPRO administered contractors used in this study have valid workloads as indicated by the total contract dollar value and the number of production and spares contracts. On this basis, those contractors which are not within the predicted range for QA manning may well be over or under manned. The study model, therefore, should be a much better method of determining manning requirements for both contractors and AFPROs than that presently used.

Future Research

This research effort has demonstrated that regression analysis can be used to predict manpower requirements. Future research should be performed by those in a position to implement the results. One of the major problems encountered in this study was obtaining complete and accurate data. AFCMD has the authority and capability to obtain necessary data on all AFPROs under their jurisdiction. The number of AFPROs varies with time. A major advantage of a standard manpower model is that it could be used to help determine the manpower requirements of new AFPROs before they are established.

AFCMD should obtain data on factors which they believe might be significant to the manpower model. Among the factors considered should be the variables used in this research effort. AFCMD can use this data to develop two manpower models with the use of regression analysis.

The first model can use contractor QA manning as the dependent variable. This model would be comparable to the model developed in this research effort and could be used to advise contractors how their QA manning compares to that forecasted by AFPRO standards as established by the AFCMD contractor manning model. Since the Government pays for most of the contractors' manning, any savings incurred by the contractor by operating more efficiently would be shared by the Government and contractor. Since profits would be affected directly, this provides an incentive to contractors to optimize their QA manning levels.

The second model can use AFPRO QA manning as the dependent variable. This model could be used to predict and control AFPRO QA manning since AFCMD controls manpower authorizations. This would be most beneficial during the establishment of a new AFPRO or for major changes to an existing AFPRO.

Thus, one data collection plan could result in two regression analysis models which would predict a more efficient and effective balance of QA manning for the contractor and the Government. The Government and contractor would share this benefit.

APPENDIX A

QUESTIONNAIRE (PROPOSED)

QUESTIONNAIRE

Provide the following information as it pertains to the contractor managed by your AFPRO/QA organization. Answers should be as specific and brief as possible. Accuracy should be based upon the best available information provided by the contractor. Should the requested information be unavailable, a brief statement should be included as to the cause for the nonavailability.

1. Provide the following information as it relates to the present operation of the contractor's QA organization:

a. A brief description of each major contractual end item requiring source acceptance (DD-250).

b. The present number of contracts and their dollar value requiring a contractor organization consistent with:

	No.	Dollar Value
(1) MIL-Q-9858A	________	________
(2) MIL-I-45208A	________	________
(3) Standard Inspection	________	________

2. Provide the following information as it relates to the present personnel status of the contractor at your plant.

a. Total personnel employed by contractor__________

b. Total Production Department personnel employed by contractor__________

c. The number of Quality Assurance personnel employed by the contractor at your plant as follows:

(1) Lab Support (Metrology, etc.) __________

(2) Quality Engineering __________

(3) Plans and Programs __________

(4) Material Review and Records __________

(5) Inspectors __________

(6) Total __________

3. Provide the following information as it pertains to the contractor's quality personnel manning practices.

a. Briefly describe the method used by the contractor to justify his QA manning requirements.

b. Does the contractor use a statistical model to justify or predict his QA manning requirements? (YES)(NO) If so, describe the model, e.g., dependent/independent variables, type of regression.

c. Does the present contractor QA manning correspond to the requirements of his predictive method/model?

d. The present schedule status of each major Government production contract:

Contract Title	Monthly No. of Deliverable End Items Accepted During Past Yr. (Mean and Range)	Months Behind Schedule	Is the Schedule Slip Caused By a QA Problem (Yes/No)

e. Average number of MRB actions (mean and range) for each contractual end item accepted during the past 12 months.

Major End Item (Title)	Total MRB	Use As Is	Rework	Scrap

f. The number of field reports of unsatisfactory material received by your plant within the last 12 months.

Major End Item	No. of EURs	Did EUR Result in Contractor Corrective Action (Yes/No)

g. The number of corrective action hours expended by the contractor each month (mean and range) during the last 12 months.

h. The monthly dollar value of scrapped material during the past 12 months (mean and range).

i. If the contractor's method of assessing his quality manning requirements requires information not included in any of the above questions, please provide the information as additional data below.

APPENDIX B

QUESTIONNAIRE (FINAL)

13 April 1976

Reply to
Attn of: CC

Subject: Functional Manpower Models

To: All Detachments/CC

1. The purpose of the attached questionnaire is to provide pertinent data that we will use in updating the present QA functional manpower model. The data will be shared with AFIT in support of a Quality Assurance manpower research study. Request all data be sent to HQ AFCMD/QA. The data will be sanitized prior to its being transmitted to AFIT. The sanitizing will remove all contractor identity, and thus maintain necessary contractor confidentiality. Data to be submitted will cover the timeframe 4th quarter FY 74 through 3rd quarter FY 76, by quarter.

2. Request completed questionnaire be submitted NLT 14 May 76. Contact Mr B. Martinez, ext 4-8880 on matters pertaining to attached questionnaire or related items.

1 Atch
Questionnaire

CLAY D. WEIGHT, Colonel USAF
Chief of Staff

QUESTIONNAIRE

Provide the following information as it pertains to the contractor managed by your AFPRO. Answers should be as specific and brief as possible. Accuracy should be based upon the best available information provided by the contractor. Should the requested information be unavailable, include a brief statement as to the reason for the non-availability.

1. Provide the following information as it relates to the present operation of the contractor's QA organization:

a. A brief description of each major contractual end item requiring source acceptance (DD-250) and covered by an active contract whose face value is $10 million or greater.

b. The present number of contracts and their dollar value requiring a contractor organization consistent with:

	No.	Dollar Value
(1) MIL-Q-9858A	________	___________
(2) MIL-I-45208A	________	___________
(3) Standard Inspection	________	___________

c. Number of NASA contracts in contractor plant_____

d. Number of off-site locations:

(1) Greater than 10 miles ______

(2) Less than 10 miles ______

e. Number of active contracts with a face value of $10 million or greater.

(1) Development ______

(2) Production ______

(3) Spares ______

2. Provide the following information as it relates to the present personnel status of the contractor at your plant.

a. Total personnel employed by contractor____________

b. Total Production Department personnel employed by contractor____________

c. The number of Quality Assurance personnel employed by the contractor at your plant as follows:

	1st shift	2nd shift	3rd shift
(1) Lab Support (Metrology, etc.)	________	________	________
(2) Quality Engineering	________	________	________
(3) Plans and Programs	________	________	________
(4) Material Review and Records	________	________	________
(5) Inspectors	________	________	________
(6) Total	________	________	________

d. Number of contractor personnel performing QA acceptance test functions but not assigned to the QA organization.

____

e. Provide the following information as it relates to AFPRO personnel status:

	1st shift	2nd shift	3rd shift
(1) Supervisory	________	________	________
(2) Clerical	________	________	________
(3) Engineers	________	________	________
(4) QA Specialists	________	________	________
(5) Data Monitor	________	________	________

3. Provide the following information as it pertains to the contractor's quality personnel manning practices.

a. Briefly describe the method used by the contractor to justify his QA manning requirements.

b. Does the contractor use a statistical model to justify or predict his QA manning requirements? (YES)(NO) If so, describe the model, e.g., dependent/independent variables, type of regression.

c. Does the present contractor QA manning correspond to the requirements of his predictive method/model?

d. The present schedule status of each major Government production contract:

(1) Contract title

(2) Monthly number of deliverable end items accepted during past year (mean and range).

(3) Months behind schedule

(4) Is the schedule slip caused by a QA problem (YES) (NO)?

e. Average number of MRB actions (mean and range) for each contractual end item accepted during the past 12 months.

(1) Major end item (title)

(2) Total MRB

(3) Use as is

(4) Repair

(5) Scrap

f. The number of field reports of unsatisfactory material received by your plant within the last 12 months.

(1) Major end item

(2) Number of Quality Deficiency Reports

(3) Did Quality Deficiency Report result in contractor corrective action (YES) (NO)?

g. The number of corrective action hours expended by the contractor each month (mean and range) during the last 12 months.

h. The monthly dollar value of scrapped material during the past 12 months (mean and range).

i. If the contractor's method of assessing his quality manning requirements requires information not included in any of the above questions, please provide the information as additional data below.

APPENDIX C

AFPRO RESPONSE TO QUESTIONNAIRE (TYPICAL)

RESPONSE TO QUESTIONNAIRE

1.a. See Attachment 2. Attachment 2 is a listing and brief synopsis of the major programs in progress having a face value in excess of $10 million and requiring source acceptance (DD 250).

1.b. The present number of contracts and their dollar value consistent with:

	No.	Dollar Value
(1) MIL-Q-9858A	11	$366,440,000
(2) MIL-I-45208A	16	27,650,000
(3) Standard Inspection	0	0
(4) NHB 5300.4(1B)	22	775,811,000

1.c. Number of NASA contracts in plant: 22

1.d. Number of off-site locations:

(1) Greater than 10 miles 4

(2) Less than 10 miles 0

1.e. Number of active contracts with face value of $10 million or greater:

(1) Development 6

(2) Production 3

(3) Spares 0

2.a. Total personnel employed by contractor: 5,280

2.b. Total Production Department personnel employed by contractor: 1,501

2.c. The number of Quality Assurance personnel employed by the contractor:

		1st shift	2nd shift	3rd shift
(1)	Lab Support	40	0	0
(2)	Quality Engineering	62	0	0
(3)	Plans and Programs	29	0	0
(4)	Material Review and Records	55	0	0
(5)	Inspectors	183	4	0
(6)	Total	370	4	0

2.d. Number of contractor personnel performing QA test functions but not assigned to QA organization: 33

2.e. The following information relates to AFPRO QA personnel status:

		1st shift only
(1)	Supervisory	5
(2)	Clerical	5
(3)	Engineers	4
(4)	Inspectors	23

3.a. The contractor uses a "Long Range Plan" to justify his QA manning requirements. This document is dynamic and relates management level best estimates for the type of contract and level of effort required. Functional manpower models are not adaptable to the type of business in progress or anticipated. Each contract must be assessed on its own merits, i.e., the statement of work, the peculiar quality requirements involved, the funding situation and the overall complexity of build and test, and dollar risk in relation to mission failure.

3.b. The contractor does not use a statistical model in determining manpower. See paragraph 3.a. above for rationale.

3.c. Question not applicable.

3.d. The present schedule status of each major Government production contract:

(1) Contract Title: See Attachment 2, "Program Identification and Status Summary Index."

(2) Monthly number of deliverable end items accepted during past year:

High: 30

Low: 14

Mean/Month: 22

(3) Months behind schedule: None

(4) No schedule slip due to a quality problem.

3.e. Average number of MRB actions for each contractual end item during past 12 months: Information is a composite of all major programs.

(1) Major end items: See Attachment 2 for identification major programs.

(2) Total MRB:

High: 701/month

Low: 372/month

Mean: 536/month

(3) Use as is: 78 average

(4) Rework: 312 average

(5) Scrap: 43 average

3.f. Number of field reports of unsatisfactory material received within the last 12 months.

(1) Four incoming discrepancy reports were received, three on Program A and one on Program B.

(2) Two on Program B resulted in contractor corrective action.

(3) One on Program B and one on Program A did not result in contractor corrective action because damage occurred subsequent to shipment and was not attributable to contractor responsibility.

3.g. The number of corrective action hours by the contractor each month during the last 12 months:

Manhours per month average 137,280

3.h. The monthly dollar value of scrapped material during the past 12 months:

High: $80,000

Low: 5,000

Mean: 38,000

3.i. No comment--see cover letter and Item 3.a.

APPENDIX D

QUESTIONNAIRE RESPONSE FROM AFCMD

QUESTIONNAIRE RESPONSE

1. Contractor: ______________________________

2. Contractual end item: ______________________________

3. Present number of contracts/dollar value requiring a contractor organization consistent with:

	No.	Dollar Value
a. MIL-Q-9858A	______	________
b. MIL-I-45208A	______	________
c. Standard Inspection	______	________

4. Number of NASA contracts in contractor plant: ________

5. Number of off-site locations:

   a. Greater than 10 miles ______

   b. Less than 10 miles ______

6. Number of active contracts with a face value of $10 million or greater:

   a. Development ______

   b. Production ______

   c. Spares ______

7. Total personnel presently employed by contractor ______

8. Total production department personnel presently employed by contractor ______

9. Number of QA personnel presently employed by contractor:

	1st shift	2nd shift	3rd shift
a. Lab support (metrology, etc.)	______	______	______
b. Quality engineering	______	______	______
c. Material review and records	______	______	______
d. Inspectors	______	______	______
TOTALS	______	______	______

10. Number of contractor personnel performing QA acceptance test functions but not assigned to the QA organization ________

11. AFPRO QA personnel status:

	1st shift	2nd shift	3rd shift
a. Supervisory			
b. Clerical			
c. Engineers			
d. Inspectors			
TOTALS			

12. Major Government contract historical data:

a. Contract identification: ________

b. Number of deliverable end items accepted: ________

Quarter	Mean	Range	Schedule Slippage (Months)	Slippage Caused By QA Problem

13. Number of MRB actions per contractor end item.

END ITEM:

Qtr	Mean	Range	Use As Is	Rework	Scrap	Qdr	Contractor Corrective Action

14. Corrective action hours expended by contractor:

Qtr	Mean	Range

15. Dollar value of scrapped material:

Qtr	Mean	Range

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In order to adequately administer the contracts for its large weapons systems, the Air Force colocates a detachment of Air Force personnel, predominantly civilian, in the contractor's facility. The majority of these personnel are quality assurance (QA) specialists and quality engineers. Historically the Air Force, as well as the other Department of Defense components, have had difficulty in determining the number of Air Force QA people required to accomplish the QA functions and tasks. This thesis attempts to identify significant variables which can be used to arrive at an optimum number of personnel. For purposes of research, the 20 Air Force Plant Representative Offices under the cognizance of Hq Air Force Contract Management Division (AFCMD) were selected for study. Variables to be tested were jointly developed by the researchers and Hq AFCMD. The required data were gathered from the AFPROs by Hq AFCMD and forwarded to the research team for study. Computer regression analyses, using the BMD02R Program, were accomplished and statistical significance of the variables was determined. Study results indicate that three variables were significant. Those variables were the number of production and spares contracts, the total contract dollar value and the number of material review actions accomplished.

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